Final Report

U.S. Department of Energy 2007 Solar America Showcase City of San Jose, California San Jose/Santa Clara Water Pollution Control Plant Solar Site Evaluation

San Jose, California

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City of San Jose, California
San Jose/Santa Clara Water Pollution Control Plant
Solar Site Evaluation

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Acronyms and Abbreviations

\$/kWh	dollars per kilowatt-hour
AC	alternating current
City	City of San Jose, California
CPV	concentrating photovoltaic
CSP	concentrating solar power
DC	direct current
DNI	direct normal insolation
DOE	United States Department of Energy
EPW	Energy Plus Weather
H_2S	hydrogen sulfide
kW	kilowatt
kWh	kilowatt-hour
MW	megawatt
MW_e	megawatt electric
NREL	National Renewable Energy Laboratory
PG&E	Pacific Gas and Electric Company
PPA	power purchase agreement
PV	photovoltaic
SAM	Solar Advisor Model

1.0 Introduction

This report describes the findings of a solar site evaluation conducted at the San Jose/Santa Clara Water Pollution Control Plant (Site) in the City of San Jose, California (City). This evaluation was conducted as part of a larger study to assess solar potential at multiple public facilities within the City. The U.S. Department of Energy (DOE) Tiger Team, including staff from CH2M HILL, Sandia National Labs, and New Mexico State University, conducted the evaluations in partnership with, and on behalf of, the DOE as part of the Solar America Initiative, a multi-year program aimed at accelerating demand and development of solar technologies among key end-use market sectors. Through the Solar America Showcase, DOE provides technical assistance to large-scale (in excess of 100 kilowatt [kW]), high-visibility solar installation projects that have the ability to impact the market for solar technologies through large project size, use of a novel solar technology, and/or use of a novel application for a solar technology. The City of San Jose was one of three locations awarded a Solar America Showcase award in May 2007.

1.1 Sites

Based on a list provided by the City of San Jose and in the Technical Assistance Statement of Work, the following sites were evaluated as part of this study:

- City of San Jose 4th Street Parking Garage
- Children's Discovery Museum
- HP Pavilion at San Jose
- San Jose Convention Center
- Story Road Landfill
- Las Plumas EcoPark
- Central Service Yard
- San Jose/Santa Clara Water Pollution Control Plant

The Tiger Team conducted the site evaluations on April 1-2, 2008.

1.2 Purpose and Scope

The purpose of the study was to evaluate the potential and cost-benefits for placing solar technologies on multiple public facilities within the City. The scope of the study was to provide the City with the following:

1) Determination of appropriate solar technology and size at each facility
2) Conceptual layout of a solar system for each facility

3) Estimated system cost
4) Electricity production potential and annual energy savings estimate for each facility
5) A simplified financial analysis for the highest-priority facilities.

As part of the study, the San Jose Showcase Tiger Team reviewed available data for each facility including current electrical usage, utility rate structure, site operations, and site drawings. During the site evaluations, the Tiger Team conducted an assessment of site conditions and collected relevant site data including facility orientation, roof type, potential shading, and location/availability of potential electrical interconnections.

For this analysis, the Tiger Team used publicly-available solar resource data, solar screening tools, and vendor-supplied information to assess the potential for installing a PV and/or a concentrating solar thermal electric system at the site. The solar resource data were downloaded from the National Renewable Energy Laboratory (NREL) website (www.nrel.gov) and are based on actual solar measurements and modeled values incorporating cloud cover data and satellite imagery. The Tiger Team used the PVWATTs and/or the Solar Advisor Model (SAM) screening tools (also available from the NREL website) to estimate annual energy production from the solar electric system. It is important to note that PVWatts and SAM are first-order screening tools that provide estimates of the potential peak output and energy production from a solar electric system at a particular location. The model uses the generalized capacity of the solar electric system and does not take into account design considerations such as the layout of series and parallel array strings. Further refinement of the proposed solar electric system would involve engineering design to size wiring and fuses, and determine the actual strings of modules required to create the proper input voltages and currents to the inverter. The detailed design would take into account local, state, and federal building and electric codes and would ensure that proper safety protocols are followed for interconnecting with the electric utility grid. Detailed design is beyond the scope of the current assessment.

The following sections present the findings of this study for the San Jose/Santa Clara Water Pollution Control Plant. Section 2 presents a brief analysis of the key data for the site along with a conceptual layout, size, and specification for a potential solar system at the site. Section 3 presents the conclusions and findings from this study. Section 4 presents the references used during this study.

2.0 Solar Site Evaluation

This section presents the key information used to develop the solar evaluation for the Site. The following data is presented:

- Site description and operations
- Current electrical usage and utility rate structure
- Site orientation and shading analysis
- Conceptual solar system layout
- Appropriate solar technology
- Potential electrical interconnection points
- Estimated cost
- Estimated electrical production and annual energy cost savings

Where appropriate, additional site-specific information collected during the site visit is also presented below.

2.1 Site Description and Operations

The Site is located at Zanker and Los Esteros Rd. about 8.5 miles north of downtown San Jose. The facility is used for water treatment and waste water processing. Figure 1 presents an aerial photograph of the Site.

Figure 1 – Aerial Photograph of the Water Pollution Control Plant

2.2 Current Electrical Usage

The Site has one electrical meter. The following usage data was recorded at the main meter (listed as Zanker and Los Esteros Rds) between March 2007 and February 2008:

Table 1 – Monthly Electricity Data at the San Jose/Santa Clara Water Pollution Control Plant

Read Date	kW	kWh	Total Electricity Cost ($)	Unit Cost ($/kWh)
31-Mar-07	4,892	1,752,817	$ 129,122	$ 0.074
30-Apr-07	6,167	1,613,683	$ 123,277	$ 0.076
31-May-07	5,616	1,232,189	$ 123,856	$ 0.101
30-Jun-07	4,748	490,044	$ 66,236	$ 0.135
31-Jul-07	3,949	433,137	$ 68,469	$ 0.158
31-Aug-07	2,390	409,207	$ 63,874	$ 0.156
30-Sep-07	3,550	315,140	$ 53,325	$ 0.169
31-Oct-07	3,906	591,222	$ 76,360	$ 0.129
30-Nov-07	7,571	1,487,226	$ 117,241	$ 0.079
31-Dec-07	5,346	1,897,487	$ 137,208	$ 0.072
31-Jan-08	5,252	1,535,300	$ 113,221	$ 0.074
6-Feb-08	20	5,961	$ 758	$ 0.127
Sum		11,763,413	$ 1,072,948	
Max	7,571	1,897,487		
Avg				$ 0.091

Notes:
kW = kilowatt
kWh = kilowatt-hours

The monthly electricity profile for this meter is shown graphically on Figure 2.

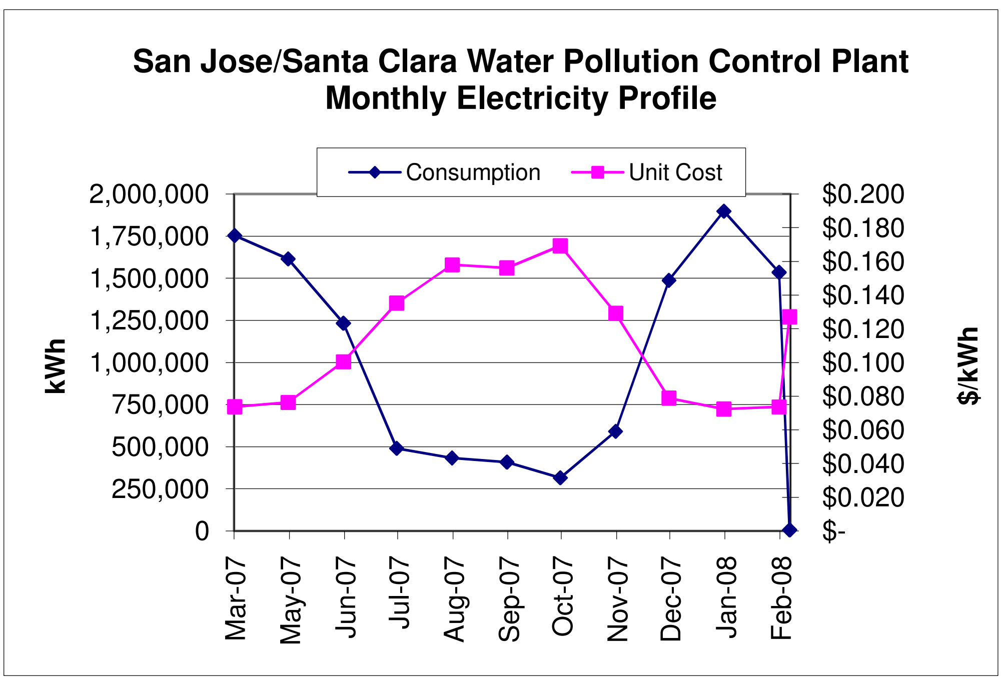


Figure 2 - Monthly Electricity Profile at the San Jose/Santa Clara Water Pollution Control Plant

Electricity service at the Site is provided by the Pacific Gas and Electric Company (PG&E) under rate schedule SE20T. The rates under this plan average $0.091 per kWh ($/kWh), with costs as high as $0.17/kWh in the summer months. There are also demand charges associated with this rate. The average electrical load for the Water Pollution Control Plant is estimated at 8.5 MW to 9 MW by Mr. Anil Kar, the Division Manager for Electrical, I&C and Power Generation. The Site generates much of its electrical load with on-site bio-gas, natural gas and methane-fed generators. The on-site generators are able to supply 13 MW at full capacity, though only approximately 7 MW of capacity is derived from bio-gas combustion.

The electric load is characterized as relatively constant since the Site operates on a 24-hour basis. During the Tiger Team site visit to the facility, Mr. Kar suggested that a 1.0 megawatt electric (MW_e) to 1.2 MW_e renewable energy system would be sufficient to compliment the current bio-gas energy production and to provide 100% of the Site's electricity needs. Because California regulations do not currently allow "wheeling" of electricity (i.e., excess electricity generated by one customer cannot be delivered to another customer, even if the sites are owned by the same entity), a solar electric plant for the Site should be designed with this limit in mind to avoid producing energy in excess of the Site's needs

It should be noted, however, that as of June 2008, there is "wheeling" legislation pending in California. The bill, AB 2466, pertains to Government Energy Producers. The legislation, if adopted, would allow multiple facilities owned by a city, county, special district, or joint powers to receive a credit on the bill of a benefiting account equal to the amount of electricity supplied to the electric grid by an eligible renewable generating facility. Specifically, the bill would allow the City of San Jose to benefit from the excess electricity produced at City facilities to power other facilities with an aggregated net metering system. If this legislation is adopted, then the City may want to consider building a larger solar plant at the Site and wheeling the excess electricity to other City of San Jose sites to meet City goals for renewable energy production.

2.3 Site Orientation and Shading Analysis

The Site is located at 37° 25′ 37.37″ North latitude and 121° 56′ 37.64″ West longitude. The large available land areas adjacent to the Site are well suited for fixed, south-facing solar arrays or single- or double-axis tracking systems. There are no large buildings or other features casting shadows over any of the major potential solar areas.

Future master planning efforts for this facility will likely consider retail or other development to the south of the facility. The development may include large buildings, towers, or other tall structures. If a tall building or structure is developed in close proximity to the designated solar area, it is possible that shading could reduce the output of a future solar system. As a rule of thumb, a building will cast a shadow three times its height during the hours of 9 A.M. to 3 P.M. Thus, if a 100 foot tall building was planned to be placed south of the solar area, a shadow spacing of 300 feet should be allowed so that the solar arrays are not shaded by the building.

2.4 Appropriate PV Technology

Based on information provided by the City, there are large areas of land potentially available for solar implementation that serves as an odor buffer. There are several renewable technologies that could potentially be used at the Site to supply the 1.0 MW_e to 1.2 MW_e of renewable power required by the Site. Possible renewable technologies could include solar photovoltaics (PV), concentrating solar power (CSP) plants, or micro-CSP systems.

The Site potentially offers several very large areas which could support a renewable power system. However, in some areas there are natural features of the land such as slopes, waterways, and vegetation that could affect the choice of technology and the design and installation of a renewable power system. In general, a ground slope of less than 3% is desirable for solar power plants, so some areas of the Site would likely have to be cleared and graded as part of project development. In addition, solar systems typically shade about 40% to 70% of the land area over which the system is installed, which may pose issues for wildlife habitats. Further study would be required to assess the technology and environmental issues associated with renewable energy development at the Site. It is recommended that future master planning efforts for the Site address potential social and environmental issues associated with site development for renewable energy projects.

The choice of technology may also be affected by elevated concentration of hydrogen sulfide (H_2S) gas present in the air in close proximity to the Site. Hydrogen sulfide gas can have corrosive effects on metals. Exposed metal parts (e.g., PV module frames or CSP support structures) could potentially be degraded by H_2S. Detailed design of a renewable power system for the Site would need to take this issue into consideration to determine the viability of using this location to generate solar electricity reliably and/or demonstrate the robustness of new solar technologies operating in a more corrosive environment.

2.4.1 Solar Photovoltaics

Solar PV technologies include high-efficiency (13%-18%) monocrystalline solar cells, average efficiency (7%-14%) monocrystalline or multicrystalline solar cells, and lower-efficiency (4%-10%) thin-film solar cells. High-efficiency solar cells are typically used in areas that are space-constrained. Average-efficiency crystalline and thin-film solar cells are typically used where cost rather than space is the driving factor. Because thin-film solar cells are generally half as efficient as crystalline silicon solar cells, solar systems based on thin-film solar modules typically require about twice as much area to supply a given amount of power as solar systems based on crystalline silicon solar modules.

Because there is significant available land area, lower-cost, lower-efficiency thin-film PV modules may be suitable at the Site. In addition, because thin-film modules are constructed using glass instead of aluminum frames, thin film modules may be more resistant to potential degradation from H_2S gas present at the Site. However, additional study would be required to determine if thin-film modules would be suitable for installation in a potentially corrosive environment.

Given the available land area, the City could install a large ground-mounted PV system at the Site. Ground-mount technologies include pole-mounted systems and ballasted systems.

Pole mounts use a heavy-gauge steel pipe that is driven deep into the ground and cemented in place. Ballasted systems use heavy concrete ballasts to support and anchor a steel rack frame, and utilize the weight of the ballast to resist wind and seismic forces. There are no penetrations required for ballasted systems, and as such ballasted systems are typically cheaper than pole-mounted systems. A geotechnical and structural analysis would be required to determine the most appropriate mounting system for the Site.

Single-axis tracking systems increase the annual energy production of a solar electric system compared to fixed-tilt systems. As a general rule, single-axis tracking systems increase annual output by 20% to 22 % compared to fixed-tilt systems, depending on location. There are several packaged, single axis tracking systems available from various U.S. and foreign manufacturers. One example is the T20 single-axis tracking system manufactured by SunPower Corporation. Figure 3 shows a PV system at Nellis Air Force Base in Nevada which utilizes the T20 tracking system. Each array is mounted on a concrete ballast and a signle motor controls the movement of multiple panels.[1] Figure 4 shows a side view of a T20 single-axis tracker at a 20° tilt. One advantage of the T20 system is that it is tilted up from horizontal, which further increases annual energy production. Most single-axis tracking systems rotate around an axis that is horizontal (or at a 0º tilt). Figure 5 shows an example of this type of tracking system at the Semitropic Water Storage District in Wasco, California. The electricity from this 1.0 MW system is used to run the water facility. One motor drive typically rotates several of the long rows of solar modules that are orientated in a north-south axis. The rows track the sun from east to west on a daily basis.

Figure 3 - Single-axis tracking solar array (14.2 MW) at Nellis Air Force Base in Nevada

[1] Note that the open space between each PV array could enable local wildlife to co-exist with a PV single-axis tracking system.

Figure 4 - Side view of single-axis tracker at 20° tilt

Figure 5 - Single axis tracking system (1 MW) installed at the Semitropic Water Storage District in California. Array is at a 0º tilt along a north-south axis.

Two-axis tracking systems follow the sun in three dimensions to further increase the annual energy output from a solar PV system. Two-axis tracking systems generally increase the annual output by as much as 35 % compared to a fixed-axis system, depending on the location. However, studies have indicated that the increased cost of the tracking control hardware (e.g., bearings and motor drives) does not justify the increased energy production. Table 2 shows a comparison of predicted annual energy output for tracking versus fixed-tilt systems based on the Solar Advisor Model (SAM). The model output is based on the Sandia PV Array Performance Model Energy Plus Weather (EPW) data for San Jose, a 0.77 de-rating factor, and crystalline modules. The comparison suggests that a single-axis tracking system can increase energy output by as much as 29% per year compared to a fixed-tilt system. A two-axis tracking system only increases energy output on an annual basis by another 6%

relative to a single-axis tracking system, for a total increase of 35% over a fixed-tilt system. Given the increase in the complexity and cost of a two-axis tracking system, and the marginal increase in performance, a single-axis tracking system is recommended for the Site.

Table 2 – Comparison of Fixed-tilt vs. Tracking PV systems in San Jose

Orientation	Annual kWh/kW-DC	Increase compared to fixed tilt
Fixed at 35º tilt	1,382	-
Single-axis at 0º Tilt	1,675	21%
Single-axis at 20º Tilt	1,783	29%
Two-axis tracking	1,859	35%

Notes:
DC = direct current
kW = kilowatt
kWh = kilowatt-hour

2.4.2 Concentrating Solar Photovoltaic Systems

A number of manufacturers are developing concentrating photovoltaic (CPV) systems. These systems utilize a number of different technologies to focus sunlight onto high-efficiency PV cells. CPV systems utilizing Fresnel lenses, mirrors, troughs, or a combination of lenses and tubes have been developed. Currently, all CPV technologies are considered developmental and no large-scale CPV systems have been installed to date.

Two different types of CPV systems are being developed by local companies GreenVolts and SolFocus. The GreenVolts system utilizes mirrors to concentrate the sunlight on high-efficiency PV cells (Figure 6). The cells are cooled passively, thus water requirements are minimized. The GreenVolts system is ballasted and does not require ground penetrations. The SolFocus system, as shown in Figure 7, focuses light using innovative mirrors and optics on a pole-mounted, two-axis tracking system. The high concentration ratio (500 to 1) optics focus the light on high efficiency (30-40%), multi-junction PV cells.

Figure 6 – Conceptual CPV system by GreenVolts

Figure 7 - SolFocus CPV system on a pole mount.

The direct normal insolation (DNI) at a site is a critical parameter for plant design and project economics. While PV systems can take advantage of diffuse or indirect light, concentrating solar systems (both thermal and PV) require DNI to operate. Only direct radiation can be focused on a target; diffuse, indirect, and scattered light cannot be focused using concentrating lenses. Concentrating solar systems are typically designed to track the sun to maximize exposure to DNI. Because concentrating systems typically cost more than regular PV systems, they are best suited for areas of the country with high levels of DNI, such as the U.S. Southwest. Figure 8 shows the DNI map for the Southwest; regions of red and dark red are considered to be suitable locations for concentrated solar power development.

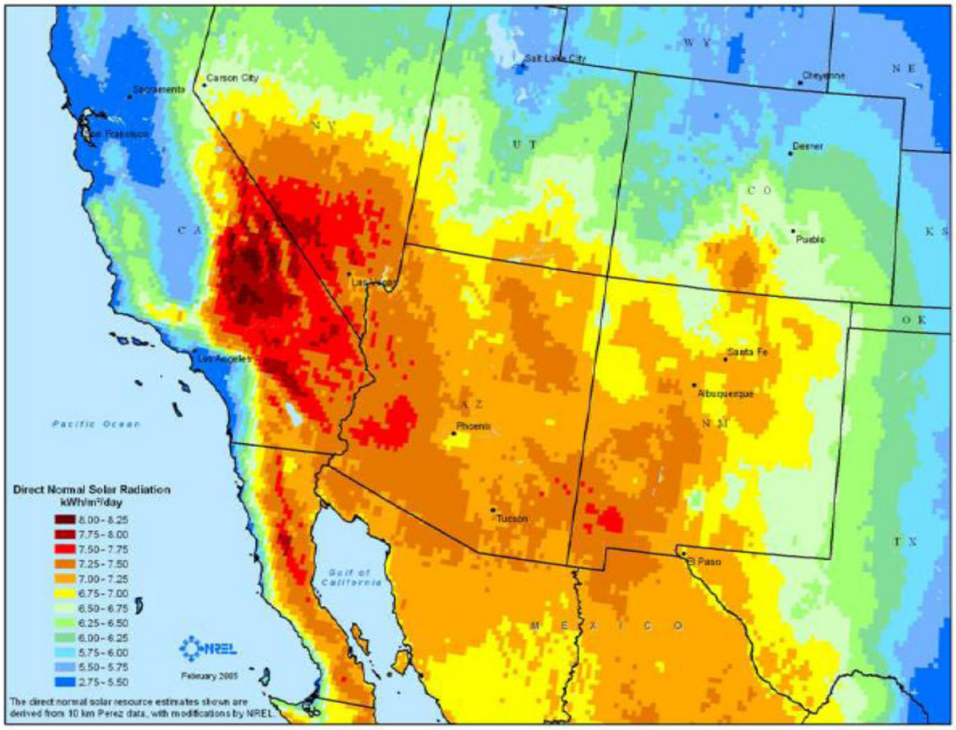


Figure 8 - Direct Normal Insolation Map of the U.S. Southwest

Based on discussions with concentrating solar power experts at NREL, project developers typically look for an average DNI of greater than 6.75 kilowatt-hours per square meter per day (kWh/m^2/day) when selecting sites for concentrating solar development. The average DNI for San Jose is 5.34 kWh/m^2/day, and therefore San Jose would not be an ideal location for concentrating solar technologies. However, the City could solicit bids from project developers or vendors to install a 1-10 MW_e pilot or demonstration CPV system at the Site. Appendix B presents additional information about prospective concentrating solar power sites in California and the DNI level for San Jose, CA.

2.4.3 Concentrating Solar Power

Concentrating solar power (CSP) systems utilize parabolic troughs or heliostats to focus sunlight onto receivers to heat a working fluid. The thermal energy from the working fluid is then converted into electrical energy through a conventional steam turbine power block. Nine CSP plants (collectively referred to as the Solar Energy Generating System [SEGS]) with a cumulative capacity of 354 MW_e were built in Southern California in the late 1980s. A 64-MW_e CSP plant (Nevada Solar One) was commissioned in 2007 in Nevada. Figure 8 shows a parabolic trough receiver. Figure 9 shows rows of parabolic troughs and the conventional power block. One advantage of CSP technology is that thermal storage units can be added to the CSP plant to improve the dispatchability of the plant to meet peak utility demand loads.

Figure 9 – Parabolic trough receiver

Figure 10 – Parabolic trough CSP plant

eSolar is a local technology vendor developing modular CSP systems. The eSolar concept utilizes heliostats and multiple small central receiver towers connected to a common power block to create a modular 33 MW_e power system. The modular 33MW_e system requires 160 acres of land. Given that the largest area at the Site is 35 acres, and considering the relatively small power requirements at the Site, the eSolar system would only be suitable for the Site in a scaled-down form for technology demonstration.

BrightSource Energy is another local provider of CSP systems using scalable central receiver technology. BrightSource Energy has recently entered into agreements with PG&E to supply up to 900 MW worth of solar energy utilizing their central receiver system. As with the eSolar system, however, the BrightSource Energy system requires significant land area and high DNI levels and is not suitable for the Site in its full scaled-up form.

2.4.4 Micro-CSP Systems

Micro-CSP systems are a category of CSP systems in the 250 kW_e to 20 MW_e range. Micro-CSP systems can be used with a smaller power block using an organic working fluid with a low temperature boiling point rather than steam. Several companies offer modular micro-CSP that can be combined to create larger (up to 100 MW) systems.

Sopogy is a micro-CSP provider targeting a market of < 20 MW size systems, and areas with a DNI level of approximately 5 kWh/m²/day. Figure 11 shows a conceptual rendering of the Sopogy micro-CSP system. Figure 12 presents technical data for a Sopogy Soponova 4.0 system, including the land area required to achieve various capacity levels (Sopogy, 2008).

Figure 11 - Sopogy Micro-CSP Conceptual System

Application Data	Soponova 4.0				
Power (kW)	250	500	1,000	2,000	5,000
Number of Panels	489	977	1,954	3,908	9,771
Space Requirements: Panel Area + Spacing					
square feet	59,854	119,585	239,170	478,339	1,195,970
square meter	5,561	11,110	22,220	44,439	111,109
acre	1.37	2.75	5.49	10.98	27.46
hectare	0.56	1.11	2.22	4.44	11.11

Figure 12 – Technical data for Sopogy Micro-CSP system. These calculations assume 850 W/m² of solar radiation.

Based on information presented in Figure 12, a land area of 27.46 acres (1,195,970 square feet) is needed to achieve 5,000 kW or 5 MW capacity. The expected energy output is 934 kWh per panel per year. ISopogy estimates an annual output of approximately 9,126,114 kWh of electricity from a 5,000 kW system, assuming 850 W/m² of solar energy. Further analysis would be required to determine the likely output from a micro-CSP system installed in San Jose.

Micro CSP systems could potentially be combined with thermal storage units to create a generation profile which matches site demand. Such a system would better meet the needs of the Site and could potentially provide energy at peak times when electricity prices are the highest.

Micro CSP systems could potentially provide a reasonable renewable power solution for the Site. Further evaluation of site-specific characteristics and the expected energy production and commercial pricing would be required to develop an economic assessment of the technology. It might be possible for the City to solicit bids from project developers or vendors to install a pilot or demonstration micro-CSP system at the Site.

2.5 Conceptual PV System Layout

Figure 13 presents a conceptual layout of potential solar development areas. The potential areas all located in the buffer area to the south of the plant. Other potentially high-value areas near Highway 237 were not included based on the assumption that these areas will be developed for retail or commercial purposes in the future. The selected potential areas are located in close proximity to the power lines and substations of the Site. Table 3 shows the approximate land areas and solar capacities, based on different technologies. Appendix A presents additional information and area calculations.

Figure 13 – Available land areas suitable for solar energy at the San Jose/Santa Clara Water Pollution Control Plant

Table 3 – Estimated Number of Modules and Approximate System Capacity

Area #	Available Land Area (ft^2)	Number of Modules	System Capacity Based on Different Types of PV Modules (MW DC_{STC})			CSP Thermal Systems MW_e
			75W Thin Film (low efficiency)	200W mono- or multicrystalline (mid efficiency)	300W Monocrystalline (high efficiency)	
1	1,002,635	22,767	1.7	4.6	6.8	4.2
2	1,554,563	35,300	2.6	7.1	10.6	6.5
3	876,149	19,895	1.5	4.0	6.0	3.6
4	231,825	5,264	0.4	1.1	1.6	1.0
5	1,195,970	36,076	2.7	7.2	10.8	5.0
Total	4,861,142	119,302	8.9	23.9	35.8	20.3

Notes:
DC = direct current
ft2 = square feet
STC = standard test conditions
W = watts

2.6 Electrical Interconnection

Figure 14 shows two substations and a natural gas peaking plant (operated by Calpine) in the vicinity of the Site. The substations could provide a suitable interconnection point for a solar system installed at the Site. High voltage interconnection points are desirable, particularly if excess generation will be exported or "wheeled" to the grid. A PV system could also be intereconnected into the main electrical distribution system for the Site. Additional switchgear may be required for interconnection of a PV system at the Site.

Potential Area #5 is located in close proximity to the Calpine peaking facility. A CSP system could potentially provide hot water, steam, or electricity to the facility, depending on the facility's needs. Further evaluation would be required to determine the best electrical interconnection point for a solar system installed in this area. It is possible that a solar system installed in this area could interconnect at the Calpine facility. If PG&E did not allow interconnection at this facility, it would be necessary to make the electrical connection back at the Site, which would require boring beneath Senter Road/Zanker Road. Under these conditions, it might not be cost-effective to install a solar system in this area. Further discussions with PG&E would be required if Potential Area #5 is pursued for a solar installation.

Figure 14 - AC Substations and the Calpine peaking facility shown as potential interconnection points

If the electrical interconnection is made at the Site, one or more commercial-scale inverters would likely be mounted outside on a concrete slab, in close proximity to existing switchgear. Figure 15 below, shows an example of a commercial 500kW inverter.

Figure 15 - Commercial-scale 500 kW PV Inverter (Xantrex model GT- 500E)

2.7 Estimated Cost

Based on a large number of PV projects installed in California, staff at the National Renewable Energy Laboratory (NREL) have estimated installation, operation and maintenance (O&M), and balance of system (BOS) costs for PV projects (NREL, 2008). The data suggest an average installed cost of approximately $6.87/watt for PV systems greater than 100 kW in size. A likely range would be $6.00/watt to $7.00/watt. However, this cost does not include materials and construction of the mounting structure, and does not include the cost for a single-axis tracking control system.

An estimated cost for installing a PV system with a single-axis tracking system in California would be $7.50/watt to $8.50/watt. This estimate assumes an additional cost of $1.50 /watt for the single-axis tracking system for crystalline based solar PV systems.

High-efficiency solar systems typically cost about $0.50/watt to $1.00/watt more than average efficiency solar systems. Installed prices for high-efficiency systems above 100kW in size would be expected to be between $6.50/watt and $7.50/watt.

The price of thin-film solar modules relative to crystalline solar modules depends on several factors, including worldwide silicon supply, panel efficiencies, supply chain efficiencies, manufacturing economics, racking systems, and other factors. Installed thin-film solar systems for utility scale projects (> 10 MW) in Germany have been reported to be as low as $4.00/ watt. An estimated cost of installing 1 MW of thin-film modules at this site would likely be in the range of $5.00/watt - $7.00/watt. The cost for installing a single-axis tracking system for thin-film solar would be higher than for crystalline silicon, because of the greater number of modules (roughly 2.5 times greater) that would be required. Based on an estimated cost of $1.50/watt for a single-axis tracking system utilizing crystalline silicon modules, a tracking system for a comparable thin-film module tracking systems might be as much as $3.75/watt. Based on this estimate, a single-axis tracking thin-film solar system would be expected to cost in the range of $8.75/watt to $10.75/watt.

Further evaluation would be required to estimate the cost of a micro-CSP system. Based on SAM, the cost of a 1 MW_e CSP trough system with an Ormat 1 MW generator would be $6,879,531, or approximately $6.88/watt). In general a micro-CSP system might be expected to cost between $6.80/watt and $10.00/watt.

Table 4 provides estimates for several different solar technologies, including crystalline silicon PV, thin-film PV, micro-CSP. The costs shown below are illustrative and may not be representative of the actual costs that would be offered to the City during a formal procurement effort.

Table 4– Estimated Power Output and Capital Costs for Various Solar Technologies

Technology	Estimated cost per kW-DC$_{STC}$ (installed)	SAM modeled kWh/kW-DC
Crystalline fixed-tilt at 35°	$6,000 - $7,000	1,382
Crystalline single-axis tracking at 0°	$7,500 - $8,500	1,675
Crystalline single-axis tracking at 20°	$7,500 - $8,500	1,783
Thin-film fixed-tilt at 35°	$5,000 - $7,000	1,486
Thin film single-axis tracking at 0°	$8,750 - $10,750	1,792
Thin film single-axis tracking at 20°	$8,750 - $10,750	1,899
Micro-CSP	$6,800 - $10,000	1,460 - 1,825

Notes:
DC = direct current
kW = kilowatt
kWh = kilowatt hour
STC = standard test conditions
W = watts

2.8 Estimated Electrical Production and Energy Cost Savings

Table 5 presents estimates of capital costs and projected electrical production based on different scenarios created using the Solar Advisor Model.

Table 5– Estimated Power Output and Estimated First Year Savings for Various Solar Systems

Area	Est. system size in MW-DC	Technology	PVWatts kWh/kW-DC	Estimated Cost	Est. 1st Year kWh production (SAM)	Est. 1st Year Savings at $0.091
1	1.70	Thin-film PV with fixed-axis @ 35°	1,486	$8,500,000, based on est. $5.00 per watt	2,526,200	$229,884
2	2.64	Thin-film PV with fixed-axis @ 35°	1,486	$13,200,000 based on est. $5.00 per watt	3,923,040	$356,997
3	1.49	Thin-film PV with fixed-axis @ 35°	1,486	$7,450,000 based on est. $5.00 per watt	2,214,140	$201,487
4	1.05	Crystalline PV with single-axis tracking @ 0°	1,675 – 1,783	$7,875,000 based on est. $7.50 per watt	1,758,750 – 1,872,150	$160,046 – 170,366
5	5.0	Micro CSP	Est. 1,460-1,825 (1)	$34,000,000 based on $6.80 per watt	7,300,000 - 9,125,000	$664,300 - $830,375

Notes:
1) The estimate of 1,825 kWh/kW is taken from vendor literature. The relatively low DNI for San Jose would likely decrease this production amount by as much as 20%. The estimate of 1460 kWh/kW is calculated based on a 20% reduction from the value in the vendor literature. .
DC = direct current
kW = kilowatt
kWh = kilowatt hour
MW = Megawatt
SAM = Solar Advisor Model (NREL)

2.9 Financing Options

2.9.1 Public Sector Solar Projects

There are several different structures available to finance public sector PV projects. Unfortunately, as a non-taxpaying entity, the City is at a disadvantage vis-à-vis corporate entities in terms of its ability to take advantage of state and federal tax incentives. This is significant since tax incentives are a key factor in making the economic case for solar. San Jose can purchase a PV system outright using the proceeds from tax-exempt municipal bond issuances similar to how it may finance other capital improvements. The City can also enter into a tax-exempt municipal lease to acquire the system, financing it over the term of the lease. However, since ownership and use of the system traditionally reside with the City in both the bond-financed and lease options, neither of these structures can take full advantage of the available tax incentives for solar. Both options also impose operations and maintenance responsibilities on the City. Alternatively, San Jose can finance PV projects through a third party using a Power Purchase Agreement (PPA) model which does incorporate the tax benefits to the benefit of the City. Similar to the lease option, no up-front capital is required on the part of the City, which makes this model more attractive for municipal entities.

Under the third-party PPA model, a solar developer finances, installs, owns, and maintains the PV system on the customer's roof. The customer (i.e., the City) would sign a long term contract (the PPA) and agree to purchase 100% of the electricity produced by the PV system. The initial cost of electricity in a PPA is typically competitive with current utility electricity rates and will typically escalate over the life of the contract at a fixed annual percentage (e.g., 2-3% per year). The solar developer and its financial backers can take full advantage of the Federal investment tax credit, accelerated depreciation, and any available state incentives. Third party maintenance is another attractive feature of the PPA model.

However, there are caveats to the third party PPA model. As the City is not the owner of the system, it cannot claim ownership of the environmental attributes of the system. This means that the City can not claim to be "solar powered" since a separate entity owns the rights to claim the solar attributes of the system. Instead, the correct terminology is that the building is "hosting" solar panels. However, the City could bolster its sustainable credentials by purchasing renewable energy credits in the amount equal to the production of the PV system. A second caveat is that the City must agree to third-party access to the PV system located on a city rooftop or on city land. Third, transaction costs are high given the number of parties and contracts involved. Finally, there may be contractual barriers within the City's charter or within the local regulatory environment that might limit the ability to enter into long-term, third-party contracts for electricity.

The third party PPA option can be structured so that the City can purchase the system prior to the end of the contract. At the end of the PPA, there will likely be three options available to the City. There will be the option for the City to purchase the system, to renew the PPA, or request that the system be removed.

It is important to point out that the 30% Federal investment tax credit for commercial PV reverts to 10% as of January 1, 2009, unless it is reauthorized by Congress. Should the reauthorization not take place, the economics of the third-party PPA model will be materially impacted and alternative structures may become more attractive to the City than they currently are today.

2.9.2 Solar Technology Demonstration

In accordance with the City of San Jose's recently adopted (5/16/08) technology demonstration partnership policy, San Jose can negotiate a variety of financial terms and conditions with solar companies that would like the City to host the demonstration of their newly introduced technologies. These financial options could range from the provision of rent-free land with a PPA for free or wholesale electricity for the WPCP to market-rate rent and provision of electricity at a market rate. If City policy permits, an equity stake in the prospective solar company could be part of the terms and conditions as well.

3.0 Findings

The San Jose/Santa Clara Water Pollution Control Plant has most of the major components of a suitable solar site for electricity generation and technology demonstration. It has undeveloped plots of land area, a relatively constant and high electrical demand, a willing technology demonstration partner in the City of San Jose, and reasonable options for interconnectivity.

Large areas of available land could be utilized for solar energy production. Up to 35.8 MW of peak power could be generated with high-efficiency solar PV modules installed over the 111 acres of identified areas shown on Figure 13. This system would cost an estimated $232,000,000 based on a price of $6.50 per installed watt.

Using less expensive solar technologies, a system size of 11.88 MW is estimated, based on a combination of thin-film solar panels installed at a fixed-tilt, crystalline panels with single-axis tracking, and a micro-CSP system. The estimated cost of this system would be approximately $71,000,000 based on the costs described in Section 2.7. The electrical output of the 11.88 MW site would be approximately 19,147,130 kWh/year based on SAM using San Jose weather data.

When evaluating the solar options for the Site, the City of San Jose should consider that solar integrators typically provide price point advantages at systems greater than 1 MW DC_{STC} in size. It is estimated that the installed cost at this site would be between $5.00/watt for a fixed-tilt thin-film system to $7.50/watt for a crystalline silicon PV system using a single-axis tracking unit.

A CSP system would not be cost effective at this location due to insufficient acreage and sub-optimal DNI values. However, it might be suitable for a small demonstration CSP plant to test the viability of various CSP systems (especially micro-CSP). A 5.0 MW micro-CSP plant would require approximately 27 acres of area.

The Site could use the solar production to offset the current electrical consumption at the Water Pollution Control Plant. Based on the current regulatory environment, the PV system should not exceed approximately 1.2 MW in size. However, if AB 2466 is passed, the City could potentially utilize the large land area available at the plant to produce electricity in excess of plant requirements, and could utilize this production to offset utility bills at other City locations.

4.0 References

National Renewable Energy Laboratory (NREL), 2008. "Installed PV Costs_Summary". Data collated by Jesse Dean of NREL. Spreadsheet provided via personal communication with Vipin Gupta of Sandia National Laboratories. March.

SOPOGY. (2008). Micro CSP: A Scalable Solar Solution for Distributed Generation, Process Heat & Air Conditioning. Available at: http://www.sopogy.com/pdf/contentmgmt/SopogyWhitePaperFINAL.pdf.

Appendix A
Solar Area Analysis

The calculation for the approximate number of modules, and the expected DC_{STC} output is found using the following methodology:

1) Calculate the available roof area via physical measurements and/or an estimate using satellite imagery.

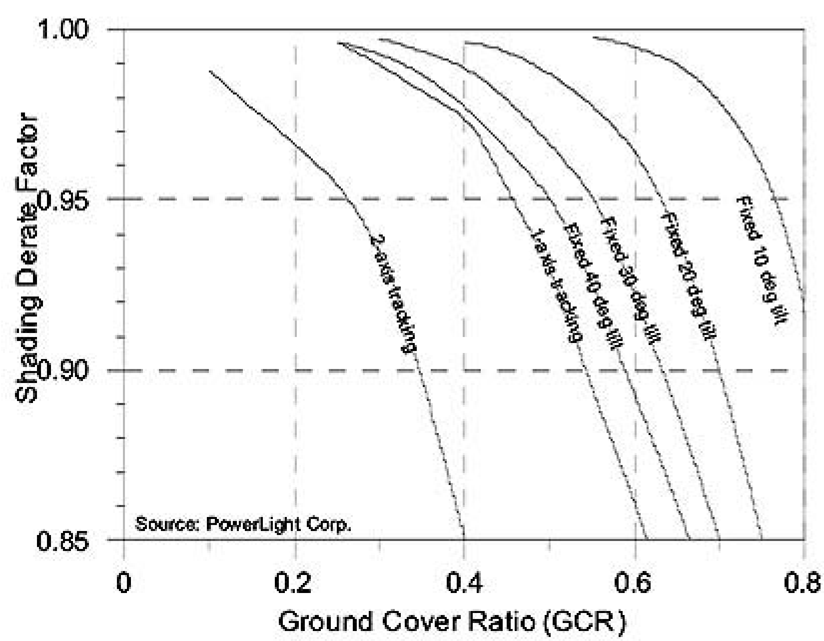
Potential Area #4: 231,825 ft^2 available area

2) Area Shape Factor for imperfect areas, odd angles, and incomplete rows.

Area #4 will have a factor of 1.0 (no odd angles or incomplete rows)

3) Use the Ground Cover Ratio (GCR) chart from PVWatts to calculate the GCR factor to allow proper spacing between modules based on tilt, shading, and spacing between modules.

For area #4 in the Water Pollution Control Plant, use single-axis tracking, or a fixed system at a 37° tilt for maximum electric output. Assume 2.5% shading, or a Shading Derate Factor of 0.975. The GCR is estimated at 0.4, based on the corresponding curves in the chart below. Of the 231,825 ft2 of area, only 40% will be solar panels from an overhead, or satellite view.



Source : PVWatts

4) Find the solar panel area by multiplying the available roof area by the GCR factor and the Area Shape Factor.

Ex: 231,825 ft^2 * .40 * 1.0 = 92,730 ft^2 solar panel area

5) Use a commonly available module size of 65″ x 39″ to estimate the number of modules available for this installation.

Ex: One module = 5.42′ X 3.25′ = 17.615 ft2

Solar module area total / solar area per module = 92,730 ft^2/17.615 ft^2 = 5,264 modules

6) Calculate the potential system size in DC kW, multiply the number of modules. Use three different technology types to estimate Peak DC system size based on various available technologies.

75W Thin-film module (5-6% efficient): 5,264 modules x 75W/module = 394.8 kW

200W multicrystalline module (13% efficient): 5,264 modules x 200W/module = 1,052 kW (1.05MW)

300W multicystalline module (18% efficient): 5,264 modules x 300W/module = 1,579 kW (1.579 MW)

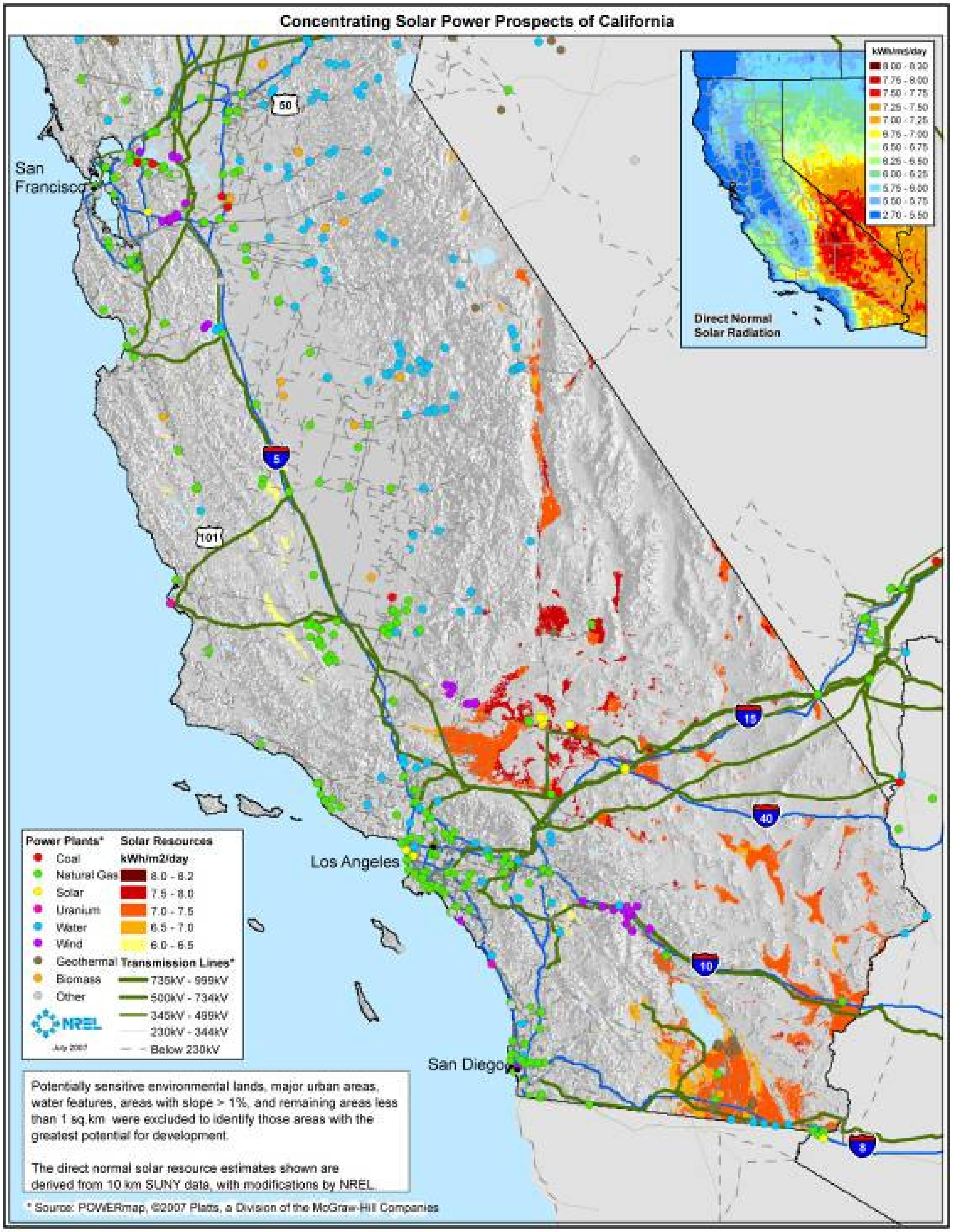
Areas

Area	Available land area (ft^2)	Shape Factor	GRC Ratio	# Modules
1	1,002,635	1	.4	22,767
2	1,554,563	1	.4	35,300
3	876,149	1	.4	19,895
4	231,825	1	.4	5,264
5*	1,588,704	1	.4	36,076

* If used for photovoltaic systems

Appendix B
Concentrating Solar Power Prospects of California

The graph below shows areas in California that may be suitable for CSP development based on DNI levels, ground slope, and distance from urban areas, water features, and sensitive lands.[2]



[2] National Renewable Energy Laboratory. (2007). *Concentrating Solar Power Prospects of California.* Available: http://www.nrel.gov/csp/images/1pct_csp_ca.jpg.

Table B-1 shows DNI data for San Jose California, based on DOE weather data[3].

- Monthly Statistics for Solar Radiation (Direct Normal, Diffuse, Global Horizontal) Wh/m□

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direct Avg	**2923**	**3500**	**2977**	**6058**	**7111**	**8087**	**7602**	**7228**	**6274**	**4924**	**3941**	**3473**
Direct Max	6196	6977	9623	8743	9181	9100	8924	8641	8329	7419	6077	5735
Day	27	19	25	20	30	25	26	5	3	1	2	22
Diffuse Avg	1072	1331	1750	2126	2249	2220	2143	1937	1733	1449	1054	900
Global Avg	2253	2954	3452	6066	7311	8102	7721	6933	5674	4069	2701	2169

- Maximum Direct Normal Solar of 9623 Wh/m□ on Mar 25

$$\text{Average Monthly Direct Normal Insolation} = (2923+3500+2977+6058+7111+8087+7602+7228+6274+4924+3941+3473)/12$$

$$=5341 \text{ Wh/m}^2 \text{ per day}$$

$$\mathbf{=5.341\ kWh/m^2\ per\ day}$$

[3] Department of Energy. (2005). Weather Data San Jose International Airport. Available: http://www.eere.energy.gov/buildings/energyplus/weatherdata/4_north_and_central_america_wmo_region_4/1_usa/USA_CA_San.Jose.Intl.AP_TMY3.stat.